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CYANAMID, ITS USES AS A FERTILIZER MATERIAL

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INTRODUCTION

Cyanamid[1] is one of the oldest of the nitrogenous materials produced by artificial processes from atmospheric nitrogen. It is used chiefly as a fertilizer, either applied alone or in commercial mixtures, although a certain percentage is converted into various chemicals for industrial and agricultural uses. The large tonnage manufactured and the present interest of the public in all forms of atmospheric nitrogenous fertilizers make it seem advisable to summarize our knowledge of the behavior of the material when applied to the soil. The particular need for a discussion of the use of cyanamid is that it has very peculiar properties, which decidedly limit its use under practical conditions. Before discussing this, however, it may be desirable to describe briefly its manufacture and properties.

MANUFACTURE

The raw materials used in the making of cyanamid are coal, coke, limestone, and nitrogen from the air. The process of manufacture consists of three principal steps: (1) The production of calcium carbide; (2) the separation of nitrogen from the air; and (3) the final production of calcium cyanamide from calcium carbide and nitrogen.

The first step of the process involves the production of lime from limestone, which is a simple operation consisting merely of heating the coarsely crushed stone in a kiln, such as that shown in Figure 1, at a temperature of about 2,000° F. until it is decomposed. The lime is then mixed with coke and heated in an electric furnace to form

[1] The term "cyanamid," as used throughout this circular, refers to the commercial form of calcium cyanamide.

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calcium carbide. At frequent intervals the molten carbide is tapped from the furnace into iron cars, is allowed to cool, is crushed, and is thoroughly powdered. (Fig. 2.)

The second step consists of securing pure nitrogen from the air. Normal air contains nearly 80 per cent of this element, mixed mostly with oxygen but also with carbon dioxide, water vapor, and relatively small percentages of various other gases. In order to secure the nitrogen free of other constituents, the air is liquefied and by distillation pure nitrogen is obtained. Such a liquid-air plant is shown in Figure 3.

The third and final step consists of passing the pure nitrogen gas into ovens filled with powdered calcium carbide, with which it com-

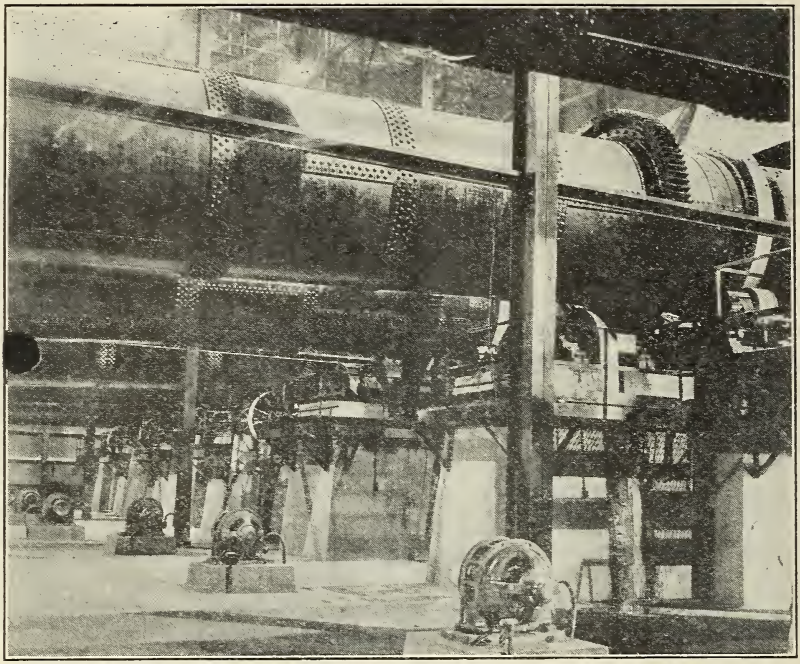

FIGURE 1.—Interior of lime-kiln building, showing rotary kilns in which the lime is burned

bines if the reaction is started by first heating a small part of it to nearly 2,000° F. The heat generated by the reaction carries the process to completion, requiring usually from one to two days in the large ovens commonly used to-day. After it has cooled the calcium cyanamide is ground to a fine powder, water is added to decompose the remaining traces of carbide and convert any free lime present into the hydrated condition, and a small amount of mineral oil is mixed with the product to decrease dustiness.

PROPERTIES AND USES

Cyanamid usually contains about 60 per cent calcium cyanamide, 20 per cent free lime, 11 per cent free carbon, 2.5 per cent water, and

small amounts of silica, iron, and aluminum oxides. It has a total nitrogen content of about 21 per cent. The large amount of lime present, mostly as calcium cyanamide and slaked lime, gives the commercial cyanamid a distinctly alkaline reaction and causes it to react vigorously with any acidic materials with which it may be mixed. Physically, it is a black powder having excellent drilling properties.

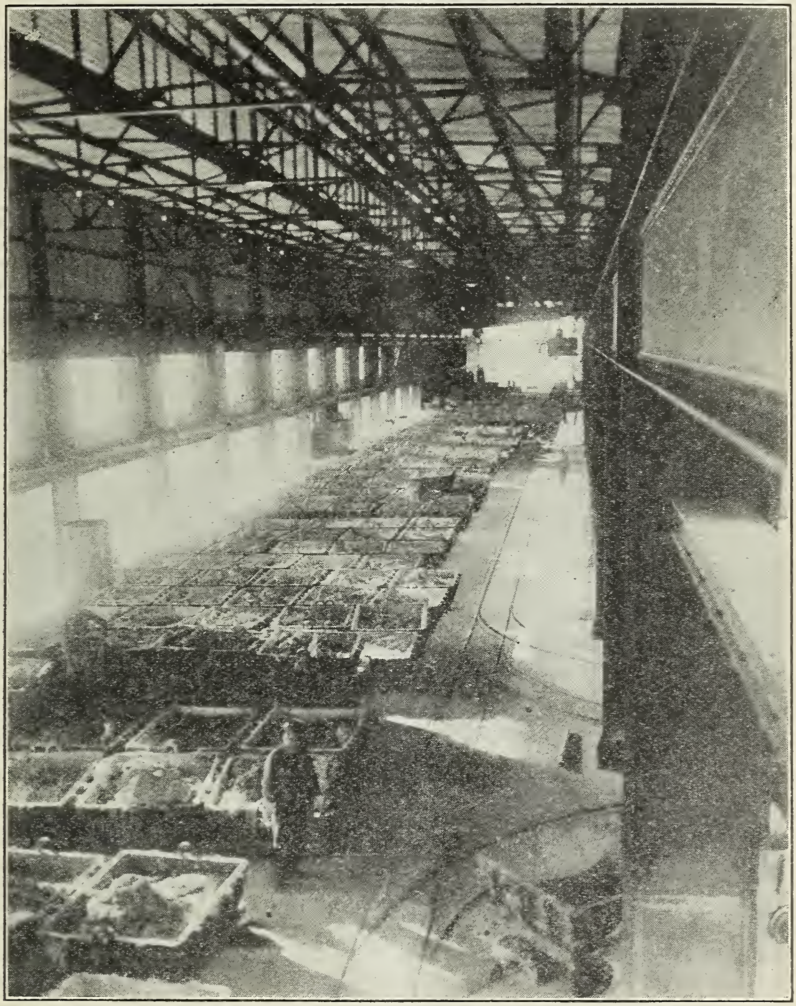

FIGURE 2.—Calcium carbide cooling shed, showing carbide in small cars prior to crushing

It is, however, somewhat dusty even after oiling. The black color is due to the inert carbon present and is of no significance. Workmen who handle the material constantly occasionally show skin inflammation. When exposed to the air, cyanamid slowly absorbs carbon dioxide and moisture, with the production of a surface crust

and a slight increase in volume. The change is so slow that it is not an appreciable factor in the commercial use of the material.

It has been estimated that about 75 per cent of the total world production of cyanamid is applied directly to the soil as a single fertilizer material. Most of this amount is used in Europe. Approximately 9 per cent is used in commercial mixed fertilizers, almost entirely in the United States. Perhaps nearly 11 per cent is used in the manufacture of ammonium phosphate and ammonium sulphate, while an additional 5 per cent is changed into ammonia and various other chemicals for industrial uses.

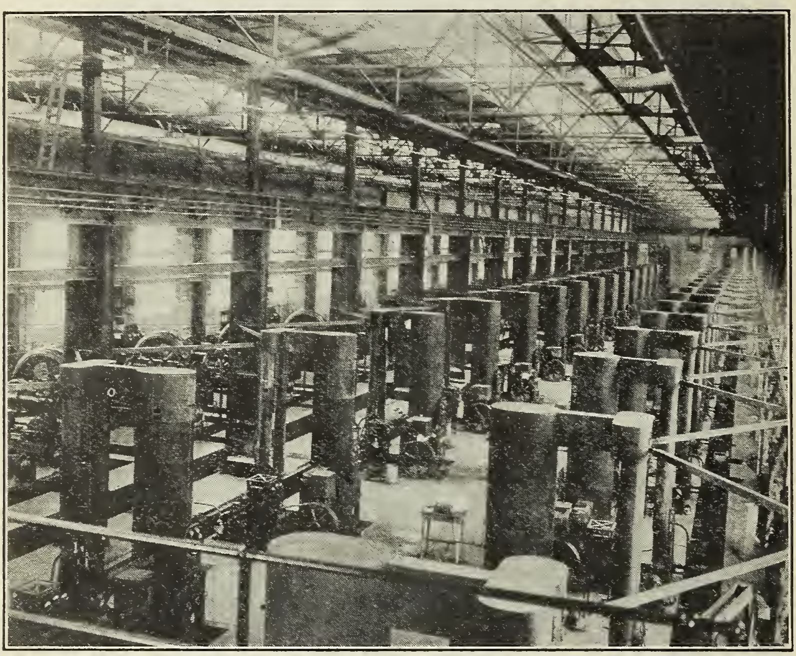

FIGURE 3.—Liquid-air plant, where nitrogen gas is separated from the other gases of the air in relatively pure form

FERTILIZER PRACTICES IN EUROPE AND THE UNITED STATES

When the large tonnage of cyanamid used as fertilizer in Europe and the comparatively small quantity used in this country are considered, it is logical to ask the reason for the difference. The explanation is largely the fact that in most of the countries of Europe a more intensive agricultural system is followed. For the most part the farms are small, labor is cheap, and farm machinery is used on a small scale only. Usually the fertilizer ingredients are broadcast singly from two to four weeks before planting, in contrast to our common practice of drilling a complete fertilizer in the row in contact with or near the seed. The result is that European practices are almost ideal for obtaining the largest yields from crops fertilized with cyanamid.

In attempting to market cyanamid on a scale in this country comparable to that in Europe, the producers have faced difficulties owing to the inherent properties of the material which limit its use in mixtures. Where used in improper combinations, particularly in large proportions with superphosphate,[2] bad results have frequently

FIGURE 4.—Ovens in which cyanamid is produced by the nitrification of powdered calcium carbide

been noted, but where used according to the best European practices, equally good results have been secured. This usually requires a change in farm practices, and hence limits the use of the material.

[2] In accordance with the recommendations of the Association of Official Agricultural Chemists and the National Fertilizer Association, as well as the new policy of this department, the term "superphosphate" has been used throughout this bulletin to replace the old name "acid phosphate."

TRANSFORMATIONS IN THE SOIL

The chemical changes which cyanamid undergoes in different soils are rather complex and can be mentioned only in part. Under optimum moisture conditions there is a rapid conversion to urea, which in turn is broken down to ammonia by biological and chemical action. Small amounts of other compounds, such as dicyanodiamide and guanylurea, both of which are undesirable, may be formed at the same time. These latter compounds, particularly dicyanodiamide, greatly retard the formation of soil nitrates and are to a large degree responsible for the slow action of cyanamid. They also probably account for many of the injuries reported in the earlier literature. With our present knowledge of the characteristics of cyanamid and how to use it the chances of injuries from such decomposition products are small. They are of importance usually only under abnormal conditions, such as where very old cyanamid is used, where improper mixtures are applied, where excessive quantities are used, where soil conditions are unfavorable for nitrate production, or where the cyanamid is not uniformly mixed with the soil.

The importance of the character of the soil needs to be emphasized, since the degree of success to be expected from the use of cyanamid is dependent to a considerable extent on the medium in which it is placed. Soils which are either very sandy, strongly acid, unusually heavy, peaty, or poorly drained and aerated are not usually suitable for cyanamid fertilization. Such environments are not favorable for the rapid production of urea, ammonia, and finally nitrates. Loam soils, which are intermediate in physical properties, are usually the most satisfactory. This is very likely to be true for other fertilizers as well, but to a greater extent in the case of cyanamid, because few commercial fertilizer materials must undergo so many changes before becoming plant foods. As has already been pointed out, cyanamid has the added handicap of being the source of agriculturally undesirable compounds which may be produced under unfavorable conditions.

The manner of application of cyanamid influences very markedly the rate and type of transformations which take place. If it is applied at moderate rates during cool weather to a suitable soil, the desirable changes may be expected. Certain of the first transformation products, when present in appreciable concentrations, are harmful to most plants. This toxic effect is ordinarily of short duration and may be of no consequence for small applications. To avoid any possible injury, however, it has been found most satisfactory to apply the fertilizer about two weeks before planting. Where this is impractical the probability of resultant harmful effects may be reduced by thorough mixing of the material with the soil.

The necessity for uniform and thorough mixing of the cyanamid with the soil is of much more importance than in the case of other fertilizers, for the following reasons: (1) The formation of desirable nitrogenous transformation products is favored; (2) cyanamid is more toxic per unit of nitrogen in the larger concentrations than other common nitrogen carriers and hence a small or moderate application might produce injuries in spots where applied irregularly; (3) cyanamid contains lime in a form that is very harmful

to seeds, plants, and microorganisms if the concentration at any one place is excessive; and (4) undesirable nitrogenous compounds are not produced to so great an extent if the cyanamid particles are in direct contact with the soil. In support of these statements, farm practice has shown that top-dressing of actively growing crops or other methods of use where the material is not well mixed with the soil often produce a retardation of growth.

IMPORTANCE OF QUALITY

It may seem unnecessary to discuss quality, for the cyanamid sold by the manufacturers in this country is of good quality. A very small percentage of the cyanamid purchased by the retail store or farmer may, however, not be used the year purchased, and if it is improperly stored there is a deterioration of the material, due chiefly to the formation of dicyanodiamide, which is objectionable in cyanamid and later in soils for three main reasons: (1) It is so very slowly decomposed in soils that it is doubtful if it can justly be considered as a fertilizer. Any cyanamid nitrogen converted into this form may in one sense be considered as lost; (2) it is extremely toxic to the soil bacteria which produce nitrates, and hence its presence in appreciable concentrations may result in nitrate starvation for the crop; (3) there is some evidence that it is a direct poison to certain plants. Undoubtedly, the effect on nitrate production is the greatest factor, and this effect may persist for several weeks. Some crops are more susceptible to deteriorated cyanamid than others, but the evidence on the subject is rather meager.

CYANAMID IN MIXED FERTILIZERS

The majority of the nitrogenous mixed fertilizers manufactured in the United States are compounded with cyanamid, which is usually used in these mixtures at the rate of 30 to 60 pounds per ton of mixture. The quantity which may be used is directly proportional to the quantity of superphosphate present. When mixed with superphosphate the lime in cyanamid combines with any free acids present and with a portion of the water-soluble phosphoric acid. If too much is used a reversion of a considerable part of the phosphate to a less available form takes place, together with the production of agriculturally undesirable forms of nitrogen.

The reasons for using cyanamid in mixed fertilizers, in addition to the fact that a cheap form of nitrogen is supplied, may be largely summarized in the one word conditioner. The lime neutralizes any free acids present in the mixture, thereby preventing bag rotting, and improves the mechanical condition by its drying action. The result is the production of a mixture which is more easily drilled and less liable to cake.

Commercial fertilizer mixtures in which cyanamid has been used at not to exceed 60 pounds per ton usually contain little or no calcium cyanamide a few hours after they are mixed. Urea is the chief of the nitrogenous transformation products, but small amounts of other compounds may also be formed. Dicyanodiamide does not form in quantities, except where the cyanamid is mixed with superphosphate in bulk, in proportions much higher than those commonly used. In

the preparation of cyanamid-superphosphate mixtures, the phosphate should be as dry as possible and the temperature be kept from rising appreciably by mixing in small lots or thin layers.

Attempts to produce a cheap available source of phosphorus that is neutral or basic and hence suitable for mixing with cyanamid in unlimited proportions have been made. The phosphate carriers of this type are basic slag and calcined phosphate, both entirely satisfactory but produced in too small quantities to be in very general use. Should these materials or others having similar properties be produced on a large scale in the future and be used in mixtures, it is probable that the quantity of cyanamid which might be used could be increased somewhat above the present practice. There would, however, be a decided limit to the increase.

CYANAMID USED ALONE

METHOD OF APPLICATION

The most ideal method of use for most cultivated crops planted in the spring is either to broadcast or apply in the row and thoroughly mix the material with the upper 3 or 4 inches of soil at least 10 days before seeding. The desirable chemical and biological changes take place more quickly and completely under these conditions, and the preliminary transformations are practically complete before the seeds are in the soil. Broadcasting without mixing with the soil is not conducive to the best results if it is done just before seeding or to the actively growing crop. Broadcasting may be practiced on permanent grasslands, on winter wheat, or on orchards, if the application is made very early in the spring before growth starts.

Cyanamid should never be drilled in the row in direct contact with the seed. A better plan is to drill the fertilizer in the usual way, follow with a cultivator that mixes the soil and fertilizer, and finally plant the seed.

RATE OF APPLICATION

The optimum rate of application of cyanamid, as compared with other nitrogen carriers, depends on a large number of factors, including the type of crop, soil, time of application, and method of distribution. Where properly used on the average soil as much as 200 pounds to the acre may be used in some cases, but this should probably be considered as the maximum. In most cases, even though its use is thoroughly understood, it is not advisable to use this amount. Better results will usually be obtained by using not more than 100 pounds of cyanamid, supplemented by other more rapidly available forms of nitrogen if desired. The smaller the rate of application, the less the necessity for extreme care in its use.

USE ON VARIOUS CROPS

Some specific recommendations for the use of cyanamid on some of our typical agricultural crops will serve as illustrations. The rates given are for the average loam soil; if light sandy soils are to receive cyanamid the application should be reduced at least 50 per cent in most cases. Furthermore, it is assumed that the method of

application conforms with the principles given, which in many cases are not the farm practices now in common use.

Corn usually responds very well to cyanamid, properly used. Corn can use ammonia nitrogen as well as nitrates and does not need to wait for the cyanamide nitrogen to be nitrified. Up to 150 pounds to the acre may be applied in any convenient manner that does not put the fertilizer in direct contact with the seed. All of the principles previously discussed apply and need not be repeated. Figure 5 shows the response of corn to a mixed fertilizer containing cyanamid as the source of nitrogen.

Small grains may receive from 75 to 150 pounds to the acre with safety. If used on winter wheat, cyanamid should be broadcast early in the spring before growth starts and should be applied only when the leaves are dry. For spring grains the fertilizer should be ap-

FIGURE 5.—Corn fertilized with cyanamid. At left, cyanamid with minerals, 1,000 pounds of 4–8–4 fertilizer to the acre; at right, no fertilizer. Source of phosphorus, calcined phosphate

plied after plowing and then mixed by harrowing or otherwise, and the seed should be sown about a week after the fertilization.

Cotton may receive up to about 100 pounds of cyanamid in the row, but not in contact with the seed. The cyanamid may be drilled in the old water furrow or in a freshly made furrow. Then a center furrow should be run through the fertilizer to spread it out and mix it with the soil. The soil should then be bedded back in the usual way and should be seeded, preferably a few days later. Side dressing for cotton is a doubtful practice. It is safer to confine the cyanamid applications to the initial one and use more quickly available sources of nitrogen for side dressings, if such are needed. Figures 6 and 7 show the growth of cotton fertilized with cyanamid in comparison with that to which no nitrogen was applied, whereas Figure 8 shows a direct comparison between growth with cyanamid and with sodium nitrate.

Truck crops or other crops which have a very short growing period or which start growth very early in the spring are not likely to respond to cyanamid in an entirely satisfactory manner. If used at

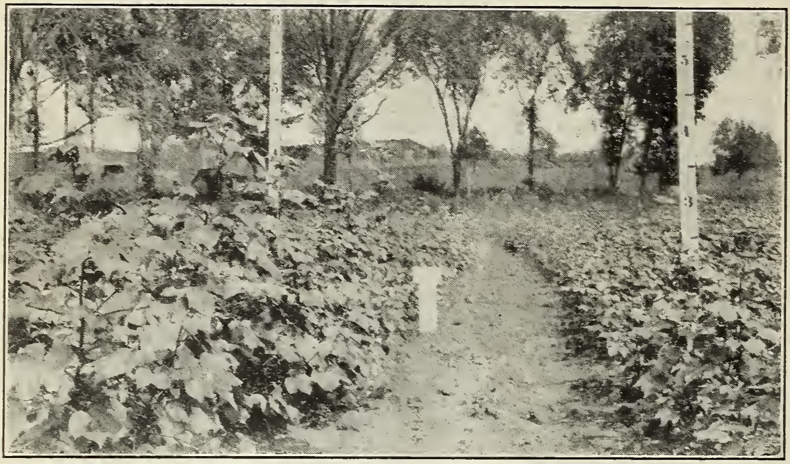

FIGURE 6.—Growth of cotton with cyanamid. At left, cyanamid with minerals, 1,000 pounds of 8–8–4 fertilizer to the acre; at right, minerals only, 1,000 pounds of 0–8–4 fertilizer to the acre. Source of phosphorus, basic slag

all, the cyanamid should be applied a long time before the seed is planted. It is better practice, however, to supply the necessary nitro-

FIGURE 7.—Growth of cotton with cyanamid. At left, cyanamid with minerals, 1,000 pounds of 8–8–4 fertilizer to the acre; at right, minerals only, 1,000 pounds of 0–8–4 fertilizer to the acre. Source of phosphorus, superphosphate applied separately

gen to such crops in the form of mixed fertilizers, supplemented by nitrates if needed.

Orchards may be fertilized very early in the spring, before growth starts, by broadcasting, followed by harrowing, provided cultivation is practiced.

The same general principles apply to all crops, and further illustrations are hardly necessary. In all of these illustrations it is assumed that the cyanamid is to be used alone, and that if phosphates and potash are needed they will be supplied separately. Cyanamid has some objectionable properties as well as good ones; the purpose here is to discuss both sides of the question and, given the facts, the decision as to its use rests with the prospective buyer. In making the final decision it will be wise to consider costs; not only the fertilizer cost, which is usually slightly lower for cyanamid, but the additional costs, if any, occasioned by any change in agricultural practices necessitated where cyanamid is used. Cyanamid should not be used indiscriminately, but if the consumer is willing to inform himself as to its peculiarities and use it according to the general recommendations given, good results may be expected.

FIGURE 8.—Growth of cotton with sodium nitrate and cyanamid. At left, sodium nitrate with minerals, 1,000 pounds of 8–8–4 fertilizer to the acre; at right, cyanamid with minerals, 1,000 pounds of 8–8–4 fertilizer to the acre. Source of phosphorus, superphosphate applied separately to cyanamid plots

SUMMARY

This circular gives the main steps in the manufacture of cyanamid, discusses its physical and chemical properties, and describes in detail how it may be used to best advantage as a fertilizer material. It is pointed out that in Europe large quantities of cyanamid are used with success, broadcast, and worked into the soil, usually a few days or weeks before seeding. In the United States very little cyanamid is applied in this manner, its use being confined largely to mixed fertilizers. At the rate not to exceed 60 pounds per ton of mixture (assuming that the mixture is a compatible one) cyanamid furnishes a satisfactory source of nitrogen and at the same time serves as a conditioner.

Where cyanamid is to be used alone, the following precautions are the most important to be considered: (1) Fresh material should be used, since cyanamid that has been stored in bags for a year or more markedly deteriorates in quality unless special precautions

have been used to keep moisture and air away from it; (2) cyanamid should not be left in contact with the hands for any great length of time; (3) cyanamid should not be mixed indiscriminately with other materials (it especially reacts with superphosphate and should not be mixed in large proportions with it); (4) heavy applications should be avoided, the maximum application usually being about 150 pounds to the acre; (5) applications should not be made in direct contact with the seed; and (6) cyanamid should not be used on poorly drained or very acid soils, where nitrate formation takes place very slowly.

Good practices for the use of cyanamid are as follows: (1) Cyanamid should be applied alone unless it is known that it may be mixed safely with the other materials with which it is desired to use it; (2) in general, it may be used in soils of good tilth, in moderate applications wherever a slowly available fertilizer is desired, provided it is thoroughly mixed with the soil a short time before seeding; (3) it may be broadcast on winter grains, grasslands, or orchards if application is made before the spring growth begins; and (4) if drilled in the row, smaller applications should be made than where it is broadcast; following application the land should be cultivated to mix the fertilizer with the soil; and finally the seed should be drilled a week or more after the fertilization.

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